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A SIMPLE, HIGH-POWER, LOW-COST NITROGEN LASER FOR DYE LASER PUM--ETC(U)
JAN 77 A FISHER, J PEACOCK, E K LEE N00014-75-C-0813

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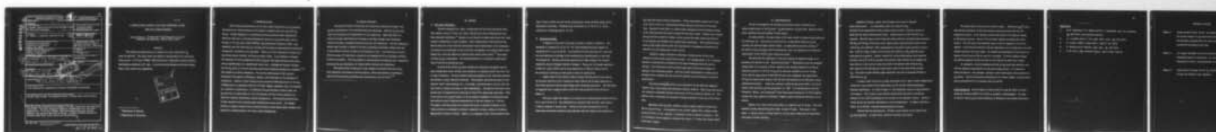

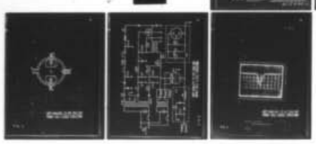

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A SIMPLE, HIGH-POWER, LOW-COST NITROGEN LASER FOR DYE LASER PUMPING

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Abstract

The design and construction of a simple, low-cost, high power N_2 laser is reported. The laser meets the optimum requirements for a dye laser pump source: 10-12 nsec FWHM, 1MW peak power, high peak-to-peak stability, and optimum operation to 50 pps. A novel electrode design and circular output beam cross section are emphasized.

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I. INTRODUCTION

The increasing appreciation of the many useful applications of N_2-pumped dye lasers has created interest in the design of cheaper and more powerful N_2 lasers. Design emphasis is on optimizing those parameters that significantly effect the efficiency of optically pumping dye lasers. An N_2-laser pump source having a 6-12 nsec pulse width (FWHM), high peak power (typically 1MW), high repetition rate (50-100 pulses per second) and low peak to peak amplitude fluctuation is generally considered to be desirable. There are a few commerical models that meet these design criteria, but they are fairly costly. In an attempt to mitigate this situation we have designed and built an N_2 laser that approximates these pump-source qualifications at a significantly lower cost. Although the design concepts for this N_2 laser are not new and many previously published designs are available,[1-4] this design has certain advantages. We use the performance of the N_2 laser described in the paper by Woodward, Ehlers, and Lineberger as the standard of comparison. Similar to their design we have achieved 1MW peak power in 12 nsec (FWHM) pulses at repetition rates up to 50 pps. Higher repetition rates are possible at a reduction in peak power. In contrast to the performance of their laser our N_2 laser has an output beam of ~ 2.0 cm diameter circular cross-section over which the intensity distribution is quite homogeneous. We find good performance at high repetition rates using the open configuration laser cavity. Our design involves a simpler construction as would be found in most lower power systems and requires no cooling system other than a small whisper fan.

II. BASIC CONCEPT

The present design is based upon the transverse discharge concept, with N_2 flow perpendicular to the exciting electrical discharge. Both the N_2 flow and electrical discharge are perpendicular to the lasing axis. High peak power is achieved through rapid build-up of charge on the high voltage laser discharge electrode through a charging system having very low inductance. The low inductance allows rapid transfer of charge to the laser discharge electrodes without loss due to self-induced reverse currents in the charging circuit. Low inductance is maintained by using low inductance capacitors and keeping all of the charging circuitry as short as possible. This necessitates a tight packing of discharge tube, capacitors, and thyratron and elimination of volumes which increase the inductance.

The subtle points of high power laser design and construction have been quite adequately described in previous papers, where disucssions of mechanical and electrical properties affecting laser performance may be found.[1-3]

III. DESIGN

A. The Laser Resonator

We have employed the "open" configuration for the laser-discharge tube. The relative merits of "flat" and "open" channel laser tube configurations have been discussed elsewhere.[3] Because of our interest in high peak powers the "open" channel configuration is more suitable. This configuration avoids interferring effects from the cavity walls but necessitates rapid replacement of the lasing gas to prevent the accumulation of the long-lived, metastable, non-lasing triplet state. Ideally the cavity gas should be replaced after nearly every pulse.[3] This leads to large N_2 gas consumption. We settled therefore on a moderate replacement rate of ten cavity volumes per sec.

In most of the earlier N_2 laser designs the discharge electrodes used in open configuration laser cavities were aluminum or stainless steel[3] and were 1cm or less in diameter. We have instead employed graphite as the electrode material and utilized a larger diameter electrode. The graphite electrodes produce a very uniform "glow" type discharge (i.e. no arcing). and have been in use for over one year with no evidence of pitting or other degradation. The special electrode cross-section that we employed was conceived by Bruce[5] for spark gap electrodes. This cross-section was created using a 2.54 cm diameter graphite rod flattened along one surface to give a diameter perpendicular to the flat surface of ~1.85 cm. The edges of the flat surface are rounded off to give a smooth transition to the round surface in an attempt to provide a transition having a radius of curvature appropriate to Bruce's results. Figure 1 is a diagram of the cross-section of the

laser cavity in which one can see the approximate cross-sectional shape of the discharges electrodes. Utilizing these electrodes in a 5.72 cm I. D. cavity resulted in a discharge gap of ~2.0 cm.

B. Discharge System

A diagram of the laser discharge circuitry is shown in Figure 2. The discharge is triggered by an EG & G HY 1102 hydrogen thyratron capable of switching 20 kV at up to 120 kA. The thyratron current rise time is 7 nsec and the tube inductance according to the manufacturers specifications is less than 15 nanohenries. Storage and firing capacitors are high-voltage D-C ceramic capacitors made by Sprague Electric Company. There are 15 storage capacitors of 3300 pF rated to 30 kV and 18 firing capacitors of 1300 pF rated to 40 kV. The estimated inductance of both types is about 10 nanohenries.

Copper sheet 5 mils thick is used to connect the thyratron to one side of the storage capacitors and to connect the other side of the storage capacitors to the firing capacitors and the high voltage laser discharge electrode. The thyratron is triggered with a negative pulse of 400-500 volts produced by the circuit in Figure 2.

The laser cavity (see Figure 1) is made from a polycarbonate tube of 6.35 cm O. D. and 5.72 cm I. D. The electrodes are mounted with 12 bolts, each with an o-ring to maintain a vacuum seal. Placed in the plane perpendicular to the electrodes and spaced regularly along opposite sides the length of the cavity are

gas inlet and vacuum outlet connections. These connections consist of 9.5 mm O.D. and 6.0 mm I.D. polycarbonate tubing expoxyed into bores in the laser tube. Inserted in each inlet is a small nozzle designed to cause turbulent mixing of the entering fresh laser gas to evenly fill the laser cavity. Without such nozzles the gas flow from inlets to vacuum outlets across the laser cavity was found to be too laminar and yielded a poor quality laser discharge. This inhibited attainment of high output optical power and disrupted the homogeneous distribution of intensity over the output beam cross-section.

Instead of using a dielectric reflectance coated mirror for the rear reflector we have used a quartz porro prism. In a lasing system it is a common problem to find that the by-products of the laser discharge attack the mirror coating. Use of the porro prism provides high reflectivity without danger of damage to the reflecting element. One thus avoids degraduation of output power through mirror coating loss and avoids the expense and inconvenience of mirror replacement.

The front outcoupling mirror is an uncoated 2.54 cm diameter sapphire window 6 mm thick having 16% reflectance (8% per surface). Both prism and mirror are mounted in adjustable bellows made from 12.06 cm diameter Delrin rod. The bellows with o-ring seals are mounted to flanges attached to both ends of the laser tube.

Operation of the N_2 laser requires a power supply capable of delivering 20 kV at up to 75 mA. It is possible to use a power supply with a voltage rating of only 10-15 kV if one employs a "doubling" circuit as shown in Figure 2. This L-C oscillator circuit supplies a voltage to the laser ~1.7 times the voltage output of the power supply.

IV PERFORMANCE

We have investigated five operating parameters found to influence the optical output power. of the N_2 laser: N_2 gas pressure, N_2 gas flow, applied voltage, pulse repetition rate and addition of other gases.

As stated earlier, the gas volume in the laser cavity is replaced approximately ten times per sec. This value is arrived at as a compromise between N_2 gas economy and desired higher optical output. As indicated by previous workers,[3] the optical output increases with increasing flow rate, the apparent limit being the replacement of the cavity N_2 gas volume per pulse.

We found that the dependence of the pulse energy on applied voltage or on pressure was similar to that obtained previously.[3] Operating at near the designed voltage limit of our system at 20 kV applied to the storage capacitors we find an optimum pressure of ~50 torr of N_2 and an optimum repetition rate of ~10 pps. At 50 pps the output power is 800-900 kW but as the repetition rate approaches 100 pps the output power drops to 200-300 kW with between 30 and 40% peak to peak amplitude fluctuation. Under the optimum conditions the pulse width is 12 ns full width at half maximum and the peak power is 1 MW. It is interesting to note that Woodward, Ehlers, and Lineberger[3] found these pulse parameters at 28 kV applied voltage and 3 pps, possibly indicating a slightly greater discharge efficiency in our system.

Figure 3 is a trace of the laser pulse at a repetion rate of 50 pps. The peak stability is about 12% and the pulse width is about 10 nsec. The pulse is very clean. A similar trace at 10 pps showed a 12 nsec pulse width and had essentially zero pulse to pulse variation.

Addition of helium, argon, and hydrogen were found to degrade laser performance. An interesting result was found for SF_6. Previous to the construction of the present laser we built a smaller version of about half the scale of the present model. Output powers of 400-500 kW were obtained. With this laser it was found that using mixtures containing approximately 30% SF_6 and 70% N_2 in the laser cavity output powers approximately double those of pure N_2 were obtained, with a degradation in the peak to peak stability to about 20%. With the larger design we have found that addition of SF_6 degrades laser performance in general. Similar results for various added gases were found by Levatter and Lin.[2] Both the present and smaller scale version of our design will lase with air in the cavity at about one tenth of the power level with pure N_2. With addition of 30-40% SF_6 the output power rises to the level of that of pure N_2. The peak-to-peak stability again degrades, this time to between 20-30% of that with pure N_2.

A useful result of the use of large electrodes in the "open" cavity configuration is that the cross-section of the output beam can be circular with homogeneous intensity distribution. As seen in Figure 1, the discharge volume is approximately 2 cm square. The circular cross-section results from the use of a mounting bellows for the front outcoupling mirror having a 2 cm diameter orifice. Between 10 and 50 pps the intensity distribution is very homogeneous. At higher repetition rates, up to 100 pps, intensity inhomogeneities increase.

We feel that the homogeneous, circular cross-section of the output beam is very important. It allows easy, efficient focusing of the beam.

We should add a note about the infrared output. Woodward *et al*[3] noted that with 8% reflectance of the front window lasing occurred in the IR with significant powers. In our system we found that below 17 kV applied voltage no IR lasing occurred. Above 17 kV we obtain rapidly increasing IR lasing powers. This IR lasing was dependent upon a critical alignment of the front window. It was observed however that the dependence of uv lasing power on front window alignment was very slight. By slightly misaligning the front window no lasing in the IR occurs with no loss of uv intensity. At 20 kV applied voltage and optium alignment the IR intensity is about 20% of the total laser output.

In summary, we have designed and built an N_2 laser that satisfies very well the optimum requirement of a dye laser pump source. It is simple to build and operate, very reliable, and has a novel output beam cross-section for N_2 lasers. Cost of construction excluding the H-V power supply, vacuum pump, and an estimated 60 hrs of machine time was $1700.

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FIGURE CAPTION

Figure 1: Cross-section of laser cavity: (a) graphite electrodes; (b) vacuum outlets; (c) gas inlet with inlet nozzle inserted; (d) electrode mounting bolts; (e) nuts tooled to seat o-ring around bolt and against laser tube.

Figure 2: (a) voltage "doubling" circuit; (b) equivalent circuit of laser discharge system; (c) thyratron; (d) laser tube. All resistances in ohms, all capacitances in micro-farads.

Figure 3: Laser pulse at 50 pps, 50 torr N_2, 20 kV applied voltage, 10 nsec per division; 5 sec exposure.

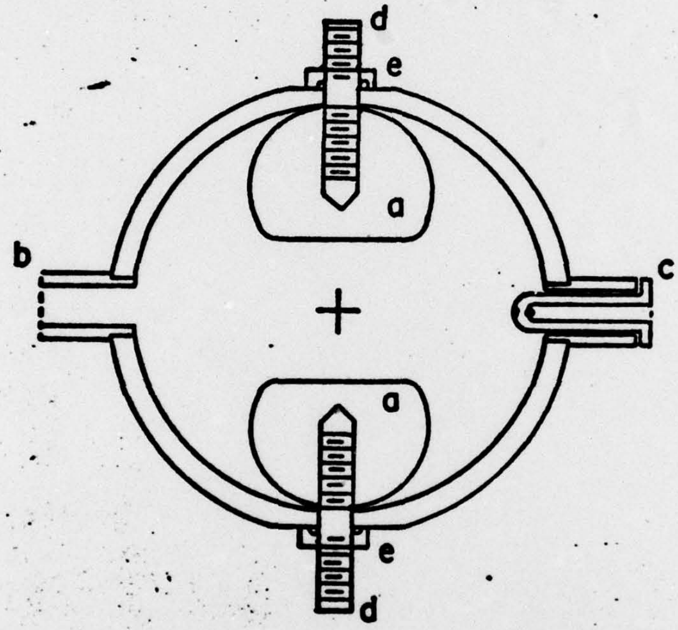
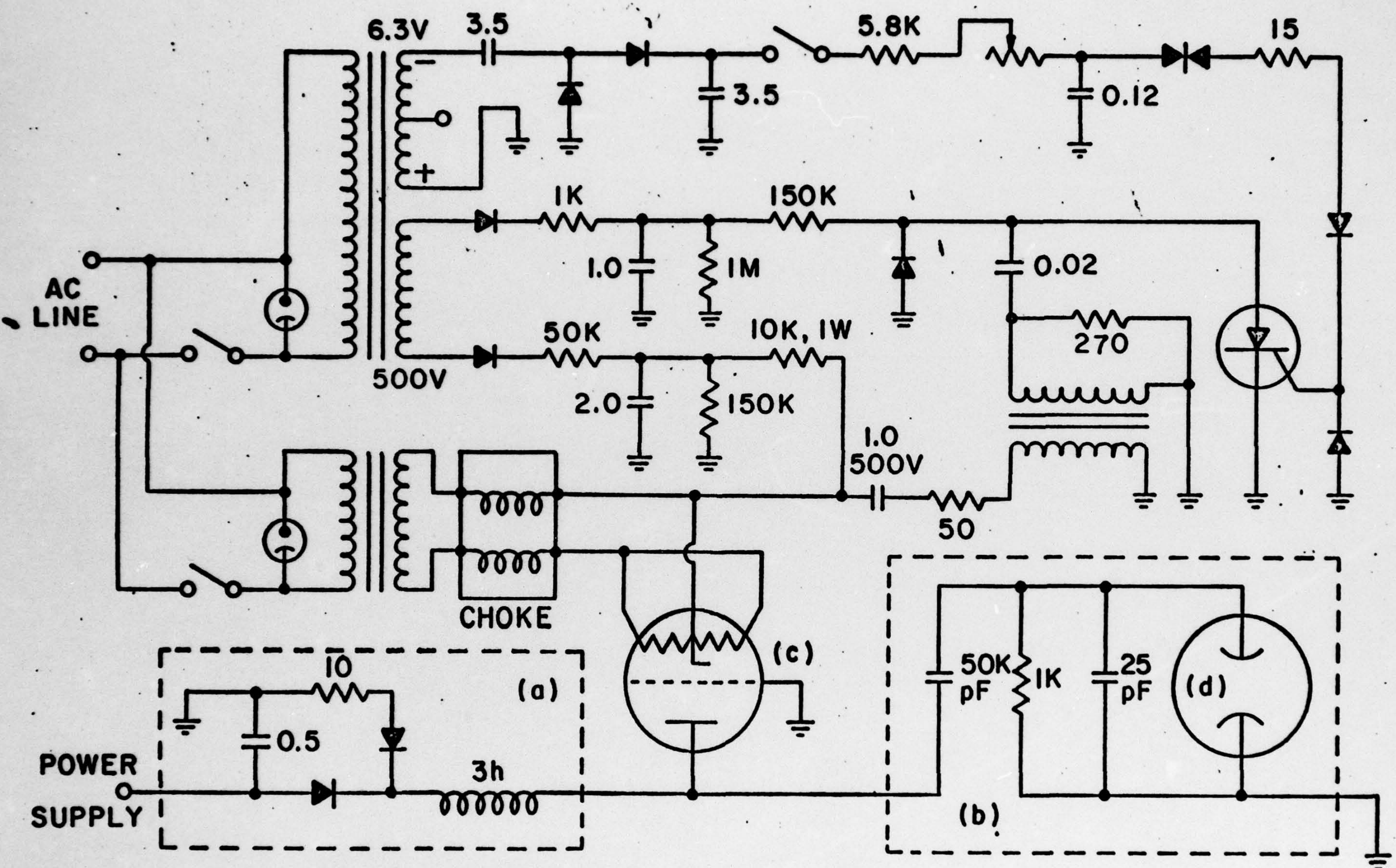


FIG 1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3.5
3.5
5.8K
0.12
15
1K
150K
1.0
1M
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AC
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270
500V
2.0
150K
1.0
500V
50
CHOKE
(c)
10
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1K
25
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FIG 2

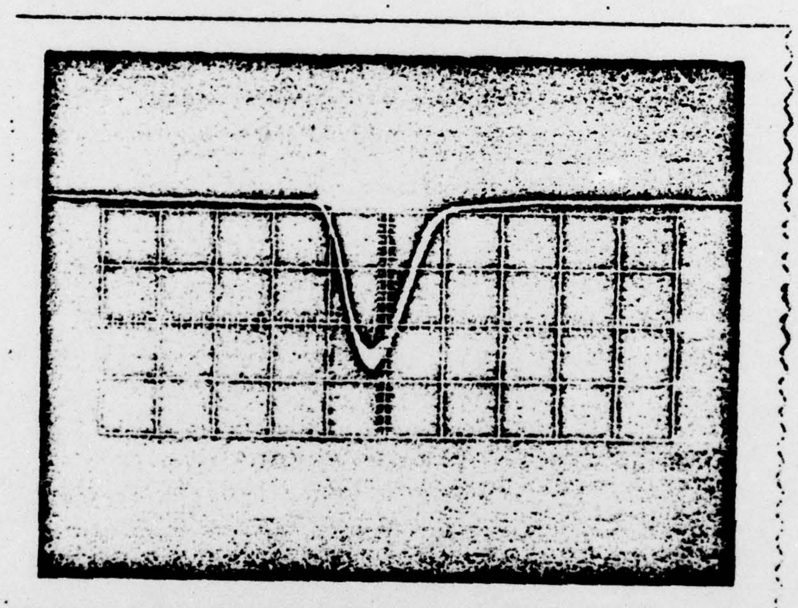

FIG 3